Assignment 10

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1 Introduction

In this assignment we focus on convolutions. In particular we perform convolutions in 3 ways. Linear, Circular and Circular using Linear convolutions. We also perform auto correlations on shifted versions of the Zadoff-Chu Sequence

2 Assignment questions

2.1 Helper Functions

A basic helper function for plotting has been used throughout the code

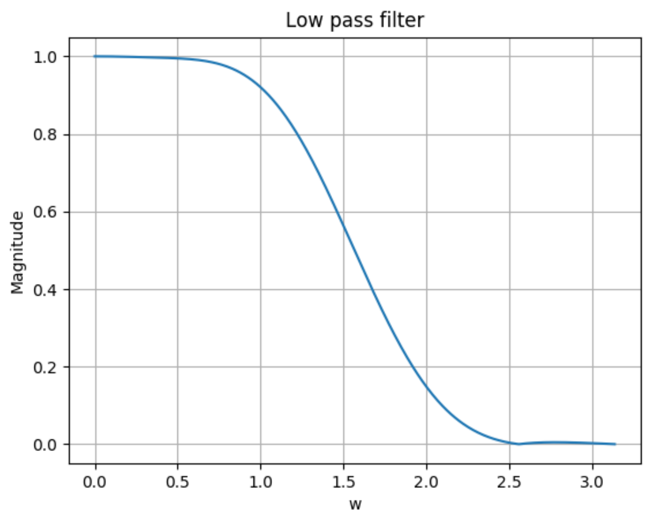
```
def plotter(x,y,x1='w',y1='Magnitude',t1='xyz',s1='x.png'):
    plot(x,y)
    xlabel(x1)
    ylabel(y1)
    title(t1)
    grid(True)
    savefig(s1)
    show()
```

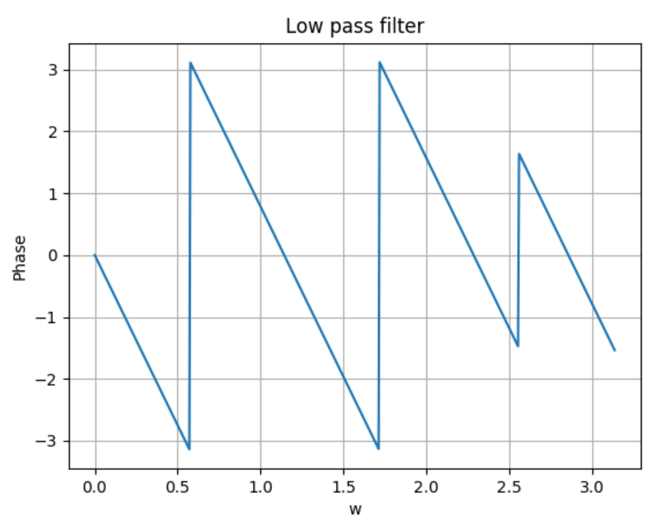
2.2 Question 2

We first use freqz to convert the given filter from the time domain to the frequency domain.

```
w,h = sig.freqz(b)
plotter(w,abs(h),'w','Magnitude','Low pass filter',"plot1.png")
plotter(w,angle(h),'w','Phase','Low pass filter',"plot2.png")
```

The plots obtained represent an LPF


Low pass filter
Magnitude
w
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0


Low pass filter
Phase
w
3
2
1
0
−1
−2
−3
0.0
0.5
1.0
1.5
2.0
2.5
3.0

2.3 Question 3

We generate the input function in this part.

```
n = arange(2**10)
x = cos(0.2*pi*n) + cos(0.85*pi*n)
plotter(n,x,'n','Amplitude','Input signal',"plot3.png")
```

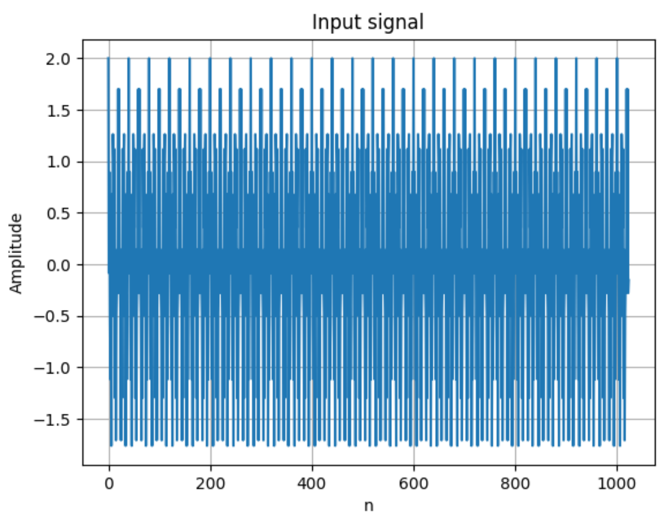


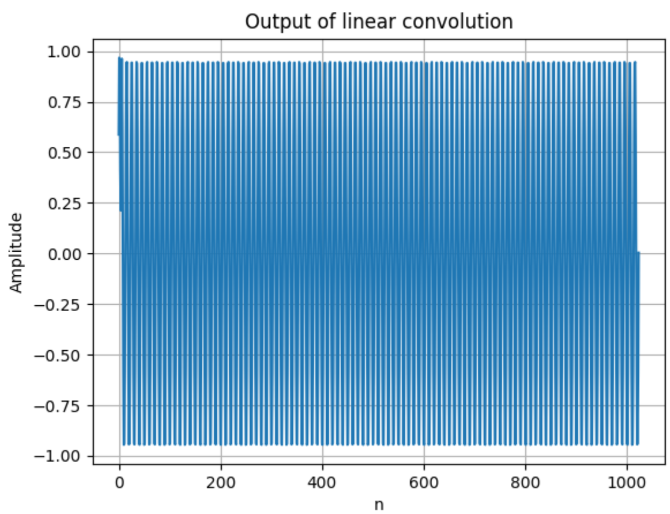
Figure 1: Fourier transform of $cos(1.5t + 0.5)$

2.4 Question 4

We first do linear convolution using the formula :

$$y[n] = \sum_{k=0}^{n-1} x[n-k]h[k] \tag{1}$$

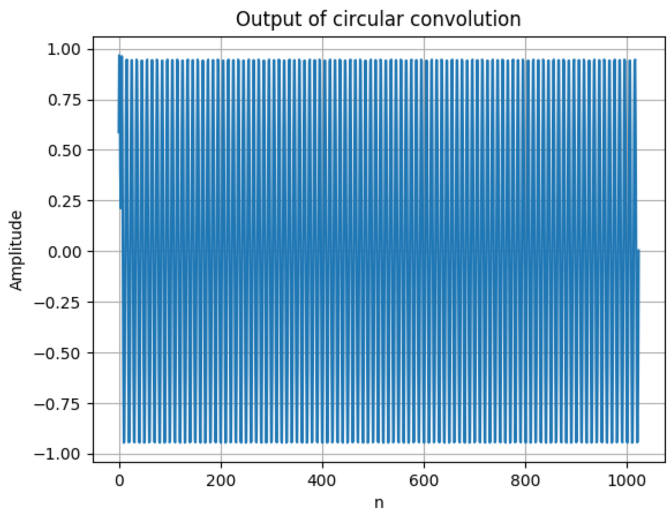
```
y = np.zeros(len(x))
for i in arange(len(x)):
    for k in arange(len(b)):
        y[i]+=x[i-k]*b[k]
plotter(n,y,'n','Amplitude','Output of linear convolution',"plot4.png")
```


Output of linear convolution
Amplitude
n
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0
200
400
600
800
1000

2.5 Question 5

We attempt to solve this more efficiently. Hence we shift to circular convolutions, where we convert to the frequency domain, multiply and go back to the time domain.

```
y=ifft(fft(x)*fft(concatenate((b,zeros(len(x)-len(b))))))
plotter(n,real(y),'n','Amplitude','Output of circular convolution',"plot5.png")
```



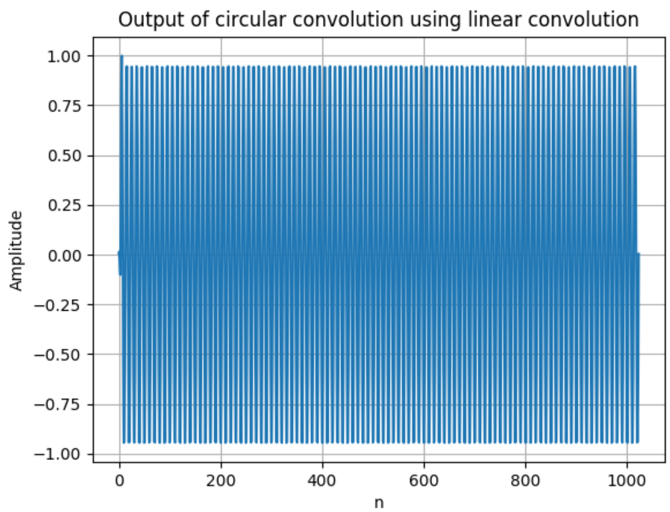
2.6 Question 5

We realize that this efficient solution is non causal and requires the entire signal to perform a convolution. We now implement a linear method of circular convolution so that we need not depend on the next infinite values in the input but only a finite number of values(this is still non causal but the delay in the response is lower)

```
def circular_conv(x,b):
    P = len(b)
    n_ = int(ceil(log2(P)))
    b_ = np.concatenate((b,np.zeros(int(2**n_)-P)))
    P = len(b_)
    n1 = int(ceil(len(x)/2**n_))
    x_ = np.concatenate((x,np.zeros(n1*(int(2**n_))-len(x))))
    y = np.zeros(len(x_)+len(b_)-1)
    for i in range(n1):
        temp = np.concatenate((x_[i*P:(i+1)*P],np.zeros(P-1)))
        y[i*P:(i+1)*P+P-1] += ifft(fft(temp) *
        fft( concatenate( (b_,zeros(len(temp)-len(b_))) ))).real
```

```
    return y

y = circular_conv(x,b)
plotter(n,real(y[:1024]),'n','Amplitude','Output_of_circular_convolution_using_linear_convolut
```



2.7 Question 6

We now examine the Zadoff Chu Sequence. The Sequence has the following properties:

- It is a complex sequence. is a constant amplitude sequence.
- The auto correlation of a Zadoff–Chu sequence with a cyclically shifted version of itself is zero.
- Correlation of Zadoff–Chu sequence with the delayed version of itself will give a peak at that delay.t

The output obtained for correlation with a shifted version of itself was completely in line with these properties Given above.

```
file2 = "x1.csv"
lines = []
with open(file2,'r') as file2:
    csvreader = csv.reader(file2)
    for row in csvreader:
        lines.append(row)
lines2 = []
for line in lines:
    line = list(line[0])
```

```
    try :
        line[line.index('i')]='j'
        lines2.append(line)
    except ValueError:
        lines2.append(line)
        continue
x = [complex(''.join(line)) for line in lines2]

X = fft(x)
x2 = roll(x,5)
cor = ifftshift(correlate(x2,x,'full'))
figure()
xlim(0,20)
plotter(linspace(0,len(cor)-1,len(cor)),abs(cor),'t','Correlation','auto-correlation',"plot7.p
```

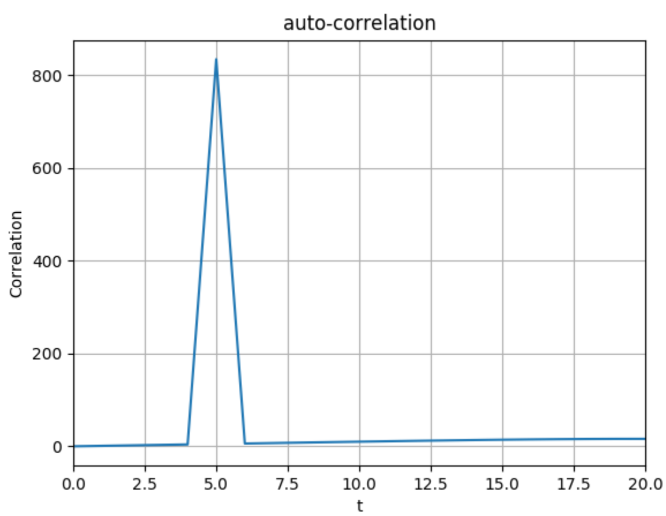


Figure 2: Correlation between Zadoff Chu Sequence and a shifted version of Zadoff chu sequence

3 Conclusion

In this assignment we have explored different algorithms for convolution. We explored Linear convolution, Circular convolution and a hybrid between the two. After that we verified the properties of the given Zadoff-Chu Sequence using correlations.